UDC 551.577.36
(420+429)

METEOROLOGICAL OFFICE
London Road, Bracknell, Berkshire

HYDROLOGICAL MEMORANDUM
No. 41

Frequencies of specified rainfall amounts within specified durations over England and Wales

by

M.C. Jackson, M.Sc. and P.R. Larke

Hydrometeorological Services (Met.O.8)
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TABLE OF CONTENTS

		PAGE
	Summary	1
	Introduction	1
	Explanation of Tables	3
	Discussion of Results	3
	Conclusions	4
	References	5

FIGURES

Figure 1	Location of autographic recording rainfall stations	6
2	Location of stations in the Surrey area	7
3	Regional boundaries used in this report	8
4	Depth-duration-frequency relationships for an 'average place' in England and Wales	9

TABLES

Tables 1A–G	Details of autographic recording rainfall stations for Regions A–G	
	Region A – Thames Basin	10
	Region B – Trent Basin	11
	Region C – North-west England	11
	Region D – South-west England	11
	Region E – Wales and the Severn Basin	12
	Region F – North-east and east England	12
	Region G – South-east England and East Anglia	13
Tables 2A–G	Frequencies of specified rainfall amounts within specified durations for Regions A–G	
	Region A – Thames Basin	14
	Region B – Trent Basin	16
	Region C – North-west England	16
	Region D – South-west England	16
	Region E – Wales and the Severn Basin	17
	Region F – North-east and east England	17
	Region G – South-east England and East Anglia	18
Table 3	Summary of median values for the 'average stations'	19

HYDROLOGICAL MEMORANDUM No. 41

FREQUENCIES OF SPECIFIED RAINFALL AMOUNTS WITHIN SPECIFIED DURATIONS OVER ENGLAND AND WALES

by M. C. Jackson, M.Sc. and P. R. Larke
Meteorological Office, Bracknell

SUMMARY

The frequency of specified amounts of rain falling in durations from 5 minutes to 16 hours is tabulated for a total of over 2000 station years. The source of the data is the rainfall returns compiled from autographic rain-gauge charts in England and Wales. The results may be compared with those already published for Scotland in *Hydrological Memorandum* No. 40.

There were 104 suitable stations in England and Wales with 10 years or more of tabulations on Metform 3441. The stations were grouped into regions labelled A to G, in order to make a regional analysis and to make the data more manageable. The low quality of some of the initial data means that very large variations are found between the mean frequencies for individual stations, and this encouraged the establishment of average results for each region.

Such an average value was calculated for each of the regions for the frequency of rainfall amounts in each column of Table 2, and these average values may be considered as representative of an 'average station' in the region. In the discussion these results are compared with those produced by Bilham,[1] modified by Holland,[2] and used continually by drainage engineers in this country.

1. INTRODUCTION

1.1 *The autographic recording rain-gauge*

Several hundred autographic recording rain-gauges are in operation in England and Wales, many of them being of the tilting-siphon variety, as described by the Meteorological Office.[3] The normal system is for a clock to turn a drum round on its axis once a day, while a pen marks a paper chart which is wrapped around the drum. The drum turns the chart past the pen at a speed of about one centimetre per hour.

The chart is usually changed each morning at 9 o'clock, when the standard manual gauge is read. The autographic rain-gauge works with the pen arm counter-balancing the rain which falls into the gauge; the pen arm is raised higher up the chart as the rain is accumulated. Usually when about 5 millimetres have been collected, the rain collected in the gauge is siphoned away automatically and the pen returns to the bottom of the chart.

An alternative, open-scale, system was introduced at some places about 15 years ago, so that short intense falls of rain could be studied in greater detail; in this system the clock moves the chart at approximately ten centimetres per hour, in contrast to the more common autographic rain-gauges.

1.2 *Compilation of data*

The rainfall observer or authority sometimes completes Metform 3440 and 3441 from the charts of either type of autographic recording rain-gauge.

Metform 3440 is a monthly tabulation of duration and amounts of rain hour by hour for the exact clock hours (e.g. 0300 to 0400, 0400 to 0500). The daily totals are adjusted as necessary to agree with daily totals from the daily rainfall check-gauge; from these daily totals, the hourly totals are adjusted to make the correct sum.

Metform 3441 is also a monthly form with rainfall duration and amount columns, but for each day of the month rather than each hour. It has columns for noting the maximum fall in given durations when more than 25 mm of rain has fallen. However, the most important entries on Metform 3441 for this Memorandum are those which give the shortest interval of time in which specified amounts of rain fell. The amounts are 5, 10, 15, 20 and 25 millimetres, and the minimum duration of this fall is noted whenever a sufficiently intense storm has occurred. The rainfall need not be continuous, nor need it be confined to one day, but any breaks are reckoned as part of the duration. The columns, one each for 5, 10, 15, 20 and 25 mm, are completed whenever possible, but no more than one set of entries is made in any one day.

One of the important difficulties, apart from that of recognizing on a chart what the minimum duration is for any specified amount of rain, is estimating sensible values when the rain-gauge ceases to operate or operates badly. Unfortunately, rain-gauges most frequently malfunction during the most intense storms, often because of debris blocking the funnel, or excess water round the gauge preventing it from siphoning correctly. Although Metform 3440 can be filled up by careful apportionment using the weather diary, reference to nearby gauges etc., Metform 3441 is quite often left without an entry in these situations, or at best with a brief note at the bottom of the form. Similarly, when there are significant discrepancies between the apparent rainfall amount from the autographic rain-gauge and the real amount from the check-gauge, Metform 3440 tabulations are altered to agree with the check-gauge values, but Metform 3441 tabulations are left uncorrected.

1.3 *Analysis of data*

An analysis by Bilham[1] of 10 years of data from Metform 3441 for 12 stations in England and Wales led to the adoption of a formula for connecting rainfall depth, duration and frequency for durations up to two hours:

$$n = 1.25\, D \left(\frac{25.4}{R + 2.54}\right)^{3.55} \qquad \ldots(1)$$

where:

n is the frequency (number of days per 10 years),

D is the duration of the event (hours),

R is the rainfall depth in the event (millimetres).

Deficiencies in Bilham's results have been apparent for many years and, with the collection of some short-duration data from the open-scale rain-gauges, a modification was made by Holland[2] to improve values for storms of short duration and high intensity. However, the general results still only relate to a mean station in England and Wales with 120 station years of record, so that, regional variations apart, values for return periods of much more than 5 years must inevitably be of doubtful quality. The Bilham formula is often extended to durations greater than two hours, even though Bilham himself was very wary of values so obtained. Unfortunately Bilham did not comment on the results previously produced by Mill[4] for the longer-duration events, and in fact the extrapolation of

Bilham's formula gives values very different from those produced by Mill from far more data.

Plant[5] showed that in Scotland there were very large departures from Bilham frequencies at all durations, even though the Bilham formula is used so frequently in Scotland.

With the vastly increased volume of Metform 3441 data now available for compilation, an attempt is made here to collect stations into regions. A detailed regional analysis is not possible, both because of the doubtful quality of much of the data, and because of the random nature of the occurrence of rare events at any one place (for example, a station may have three noteworthy falls in 10 years, followed by 30 years with none).

2. EXPLANATION OF TABLES

Tables 1A–1G contain station details for each of the regions A to G. There are a total of 104 stations in England and Wales with 10 years or more of data. Their locations are shown in Figure 1, and they are grouped into regions A to G, the boundaries of which are shown in Figure 3. The stations are numbered according to the usual hydrological scheme and are in numerical order. Although the whole of England and Wales is represented by the tabulations, the greatest density of stations is in the south-east and in the more populated parts of the country. A close network of rain-gauges was established in the Surrey area in about 1936, and this area is therefore shown separately on a larger scale in Figure 2.

Tables 2A–2G are tabulations of the frequencies of specified amounts of rain falling within specified durations at the 104 stations, as calculated from the rainfall forms 3441 for each station. Mean frequencies are presented for each station, in contrast with *Hydrological Memorandum* No. 40, which had frequencies tabulated for each individual year of record at each of the 23 Scottish stations. This has considerably reduced the size of this Memorandum without loss of the most important data. The number of years of record for each station is quoted in the second column, although the 5-minute values are of a smaller number of years. When two neighbouring stations each have a relatively short record, the two stations have sometimes been combined to give a simulated joint station with a more worthwhile length of record. (The results from several stations, mostly with only a few years of record, are not presented since their values are too extreme to be at all acceptable.)

The frequencies in Tables 2A–2G and in Table 3 are quoted as number of days per 100 years in order to simplify the reading of the tables. The number per 100 years is derived from the length of record at each station, which varies between 10 and 47 years.

3. DISCUSSION OF RESULTS

It is apparent from Tables 2A–2G that the results for individual stations are very variable. Some of the variability can certainly be accounted for by the different rainfall regimes in England and Wales, e.g. the west is more prone to longer-duration events and the east more prone to shorter thunderstorm events. Some of the variability can be accounted for by the relatively small sample of years at any one place. The rest of the variability can be accounted for by faults in the completion of the original forms, and malfunctions of the rain-gauge during heavy storms.

More reliable frequencies are obtained by grouping the stations into regions for analysis, such as the seven, A to G, adopted in this Memorandum. The number of station years in each region varies between 103 and 941; in contrast, Bilham used only 120 station years to derive his results for the whole of England and Wales. It is assumed that broadly similar rainfall characteristics typify each region, and a summary line is calculated for each region. This summary line for the 'average station', is the set of median values, each median value calculated from the stations in the column above it. The

median was calculated by taking the mean of the middle half of the ordered values, so that the bulk of the data are taken into account with little regard for the more extreme values in the column.

Table 3 collects together for broad comparison the 'average station' values for each of the seven regions. The penultimate line is a mean of these seven 'average station' values, which may be compared with the Bilham/Holland values in the bottom line. The mean values were plotted on a diagram and smooth curves drawn through the data points, as shown in Figure 4. It is clear from the comparisons provided in Table 3 that, as also found by Plant,[5] many regions have frequencies which significantly depart from the Bilham formula. We can deduce that there are actual regional variations in the frequencies of rainfall events in specified durations, and that the Bilham values are only broadly representative of an average station in the south-eastern half of England.

The values for north-east and east England (region F) have the largest differences from the overall values for England and Wales with, for example, only 12 falls of 20 mm in an hour per 100 years compared with the mean value for the country of 16, and a Bilham value of 18, whilst only 57 falls of 25 mm in 8 hours occur compared with 81 and 72 for the mean value and Bilham value respectively. This may be attributed to the low average annual rainfall; the area is sheltered by the Pennines from the prevailing westerly airstream and does not experience as many severe thunderstorms as more southern parts of the country.

By contrast south-west England (region D) experiences many more significant rainfall events for duration of 4 hours or more, and this is reflected in a map of the average annual rainfall for the country. For example, there is an average value of 93 falls of 25 mm in 8 hours per 100 years, compared with the values mentioned in the previous paragraph of 81 and 72.

4. CONCLUSIONS

Whereas Bilham calculated frequencies with duration for the country as a whole, excluding the mountainous parts of the north and west, an attempt is made here to produce individual results for several regions. The north-east and east of England is the region with the lowest values whilst for the longer durations, large values are found in south-west England. In view of the limitations of the Metform 3441 tabulation system discussed earlier, reflected in the large variability in individual station values, some kind of average value for an area seemed the best that could be chosen. A straightforward mean would have been unsatisfactory since all the extremes, including suspect data, would have been incorporated.

The resultant regional analysis, although crude, offers a first practical solution to the problem of how often a large rainfall occurs in a given duration in different parts of the country. When these frequencies are compared with the values which Bilham calculated nearly 40 years ago, significant departures are observed. The values which he calculated were based on only 120 station years, whereas this Memorandum uses over 2000 station years, and therefore must inevitably improve on his results. However, the results presented do not enable reliable estimates of frequencies of extreme rainfall events to be determined. The latter require a more powerful statistical approach such as that offered by the theory of extreme values, Jenkinson,[6] and put into practice by the Meteorological Office.[7]

The values presented in the final table (Table 3) are the median values for the seven regions, with the mean of those seven sets of values. These mean values are presented in Figure 4 and are compared with the Bilham figures in Table 3.

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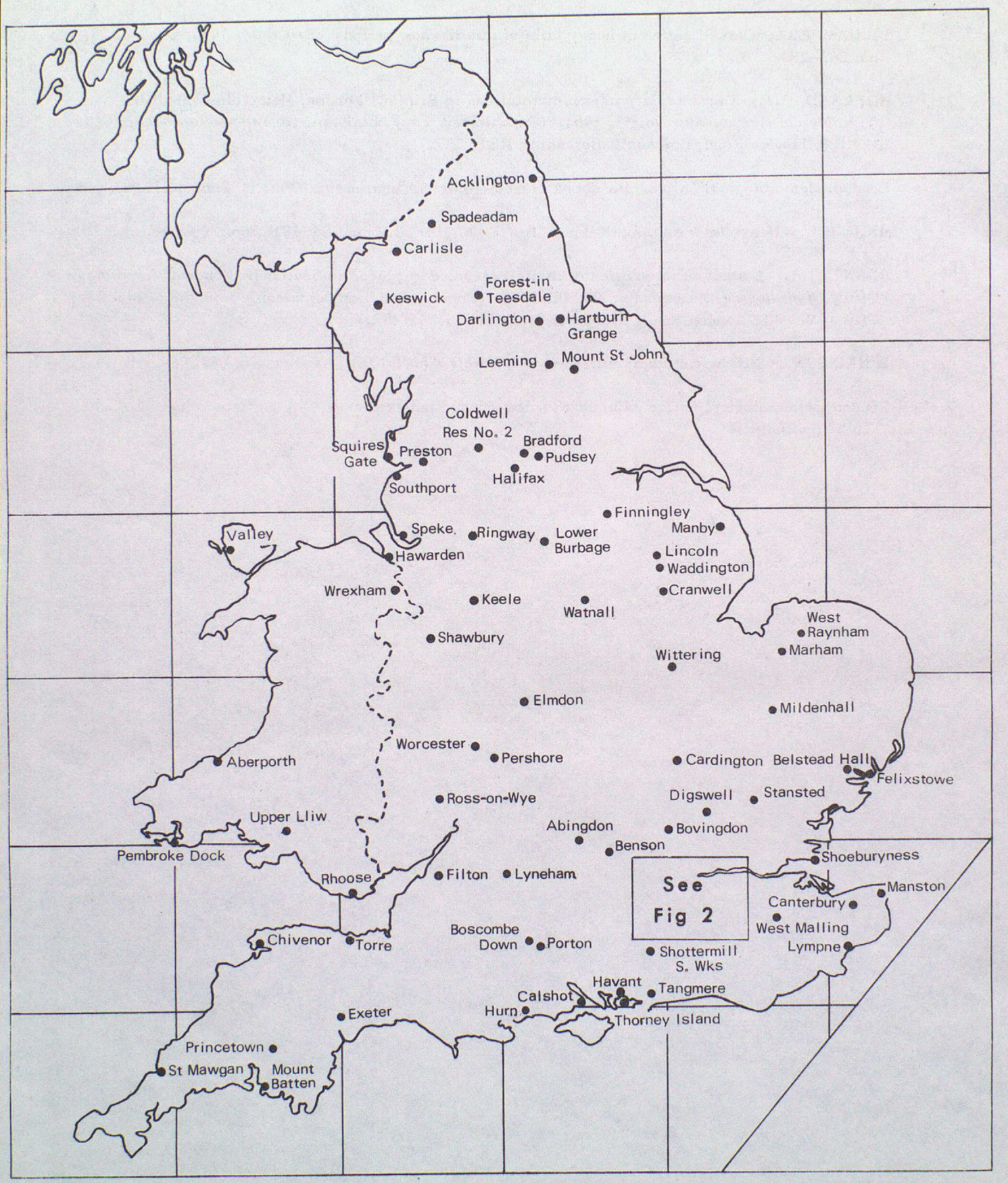

Figure 1 Location of autographic recording rainfall stations

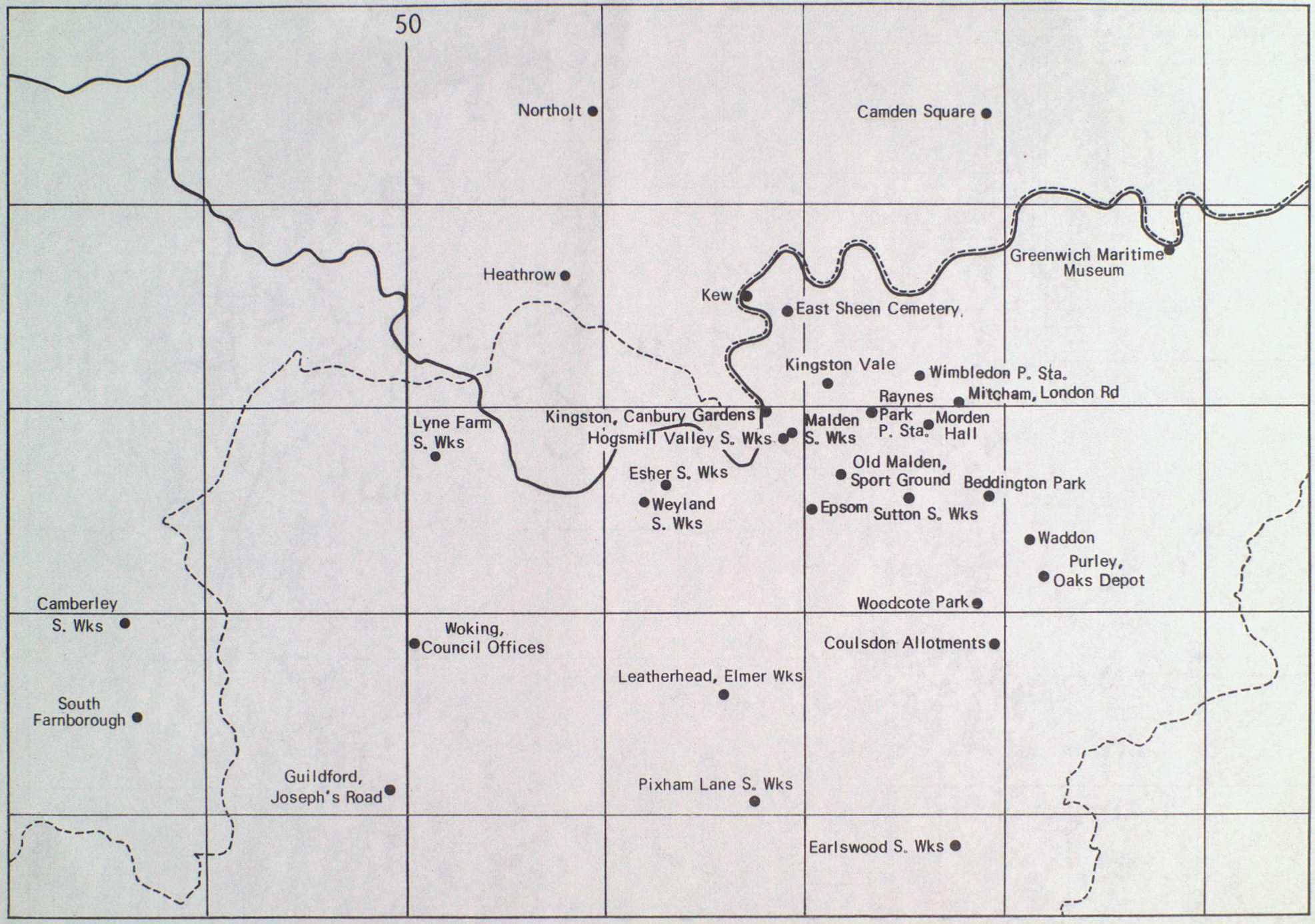

Figure 2 Location of stations in the Surrey Area

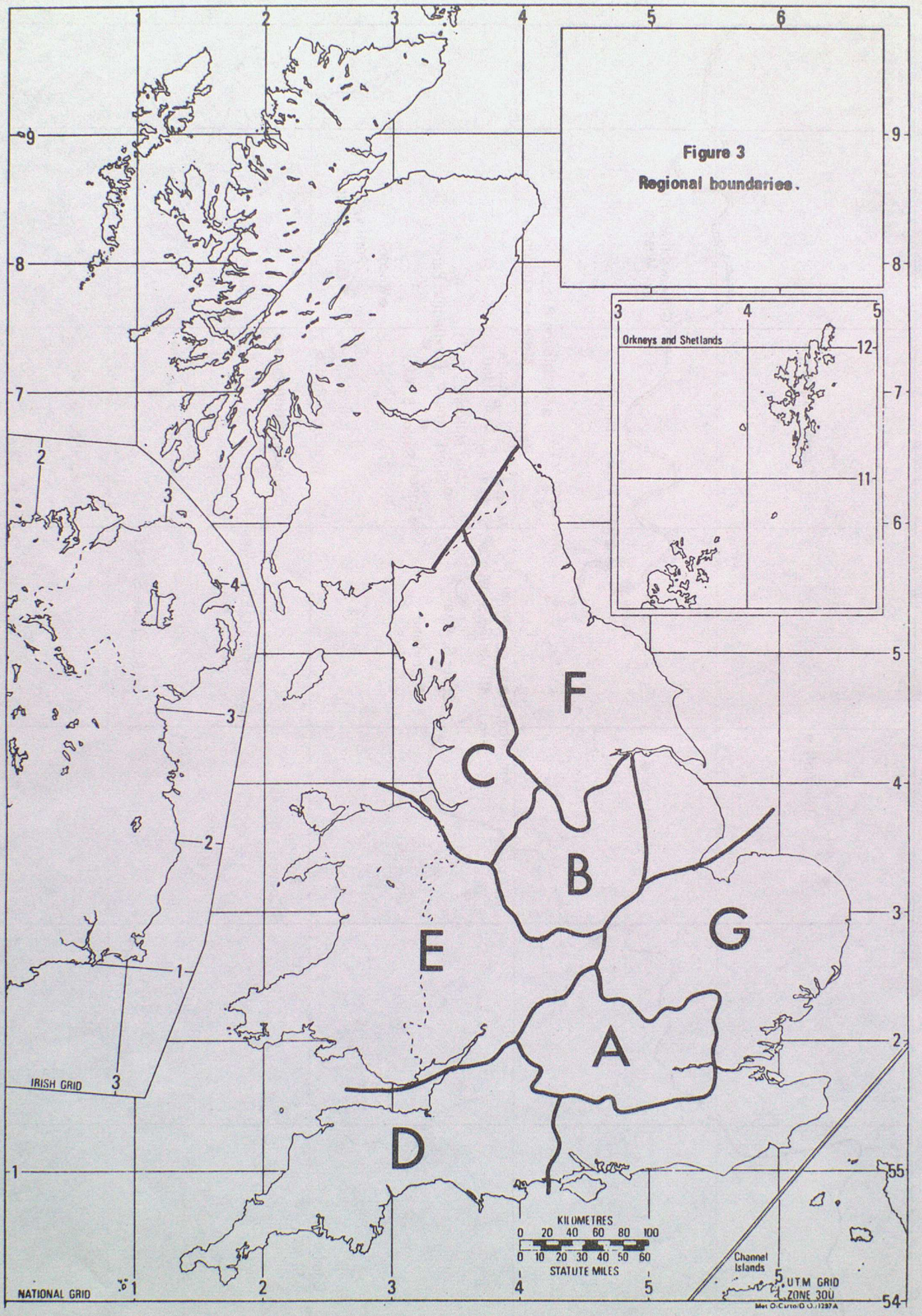

Figure 3

Regional boundaries.

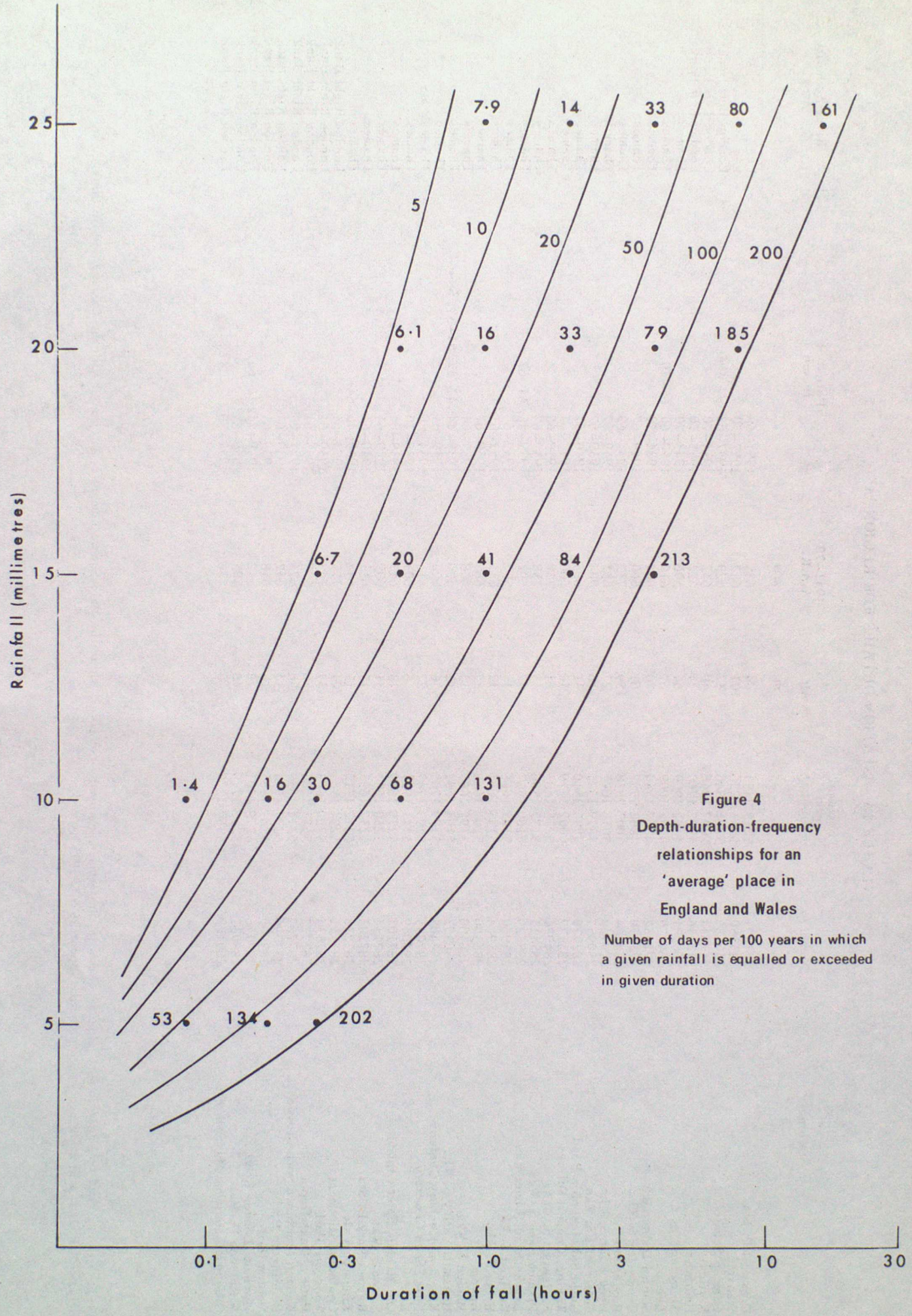

Figure 4
Depth-duration-frequency relationships for an 'average' place in England and Wales

Number of days per 100 years in which a given rainfall is equalled or exceeded in given duration

TABLE 1A – STATION DETAILS FOR REGION 'A'

Station	Number	National grid reference*	Alt.	1941–70 A.A.R.	Period of record	River Authority Area
			m	*mm*		
Digswell P. Sta.	241091	5239 2153	64	635	1951–68	Lee
Stansted	243350	5531 2226	101	642	1957–70	Lee
Camden Square	246186	5296 1846	37	629	1937–62	London Left Bank
Northolt	247344	5097 1846	40	632	1954–70	London Left Bank
Heathrow	247536	5077 1768	24	622	1947–70	London Left Bank
Abingdon	260991	4482 1990	64	596	1943–70	Thames
Benson	264270	4631 1909	67	610	1950–60; 65–70	Thames
South Farnborough	271432	4867 1544	70	664	1924–70	Thames
Camberley S. Wks	271490	4862 1597	61	660	1949–67	Thames
Bovingdon	278264	5007 2038	159	732	1954–69	Thames
Lyne Farm S. Wks	279940	5016 1677	27	631	1949–67	Thames
Shottermill S. Wks	280957	4879 1325	116	904	1939–67	Thames
Guildford, Joseph's Road	282770	4995 1510	31	683	1940–67	Thames
Woking, Council Offices	283172	5002 1579	40	660	1947–67	Thames
Earlswood S. Wks	284974	5275 1483	61	719	1939–67	Thames
Pixham Lane S. Wks	285411	5177 1506	43	758	1939–67	Thames
Leatherhead, Elmer Wks	285629	5160 1557	52	692	1939–45; 64–67	Thames
Weyland S. Wks	285960	5125 1656	15	592	1939–67	Thames
Esher S. Wks	285964	5135 1661	12	633	1952–67	Thames
Epsom	286300	5202 1648	23	665	1939–67	Thames
Malden S. Wks	286390	5197 1685	15	608	1939–64	Thames
Hogsmill Valley S. Wks	286392	5194 1682	12	606	1939–44; 47–52; 54–59; 60–64.	Thames
Kingston, Canbury Gardens	286405	5179 1700	6	600	1939–64	Thames
East Sheen Cemetery	287035	5193 1747	27	613	1934–64	Thames
Kew	287049	5171 1757	6	603	1938–70	Thames
Old Malden, Sport Ground	287101	5219 1669	18	647	1939–64	Thames
Sutton S. Wks	287144	5250 1657	31	609	1939–64	Thames
Raynes Park P. Sta.	287203	5237 1695	15	613	1940–64	Thames
Kingston Vale	287238	5212 1712	15	634	1939; 46–64	Thames
Coulsdon Allotments	287531	5294 1587	101	775	1953–64	London Right Bank
Woodcote Park	287534	5290 1603	137	745	1939–64	London Right Bank
Purley, Oaks Depot	287722	5321 1623	58	697	1953–64	London Right Bank
Waddon (combined with Croydon)	287767	5314 1639	58	674	1924–69	London Right Bank
Beddington Park	287790	5297 1654	34	647	1939–64	London Right Bank
Morden Hall	287909	5261 1685	15	618	1939–64	London Right Bank
Mitcham, London Road	287946	5278 1701	18	612	1939–44; 46–64	London Right Bank
Wimbledon P. Sta.	288031	5258 1719	18	585	1939–64	London Right Bank
Greenwich Maritime Museum	289129	5387 1776	6	586	1954–70	London Right Bank

*The National Grid reference in this paper is shown in the format used by the computer, where the Main Square number is integrated with the Easting and Northing. Thus the Digswell P. Sta. grid reference would normally appear as 52 239153.

Average annual rainfall.

TABLE 1B – STATION DETAILS FOR REGION 'B'

Station	Number	National grid reference	Alt.	1941–70 A.A.R.	Period of record	River Authority Area
			m	*mm*		
Keele	089542	3820 3446	180	801	1957–70	Trent
Elmdon	096892	4171 2837	98	688	1950–70	Trent
Lower Burbage	107054	4258 3802	281	896	1935–54	Trent
Watnall	117626	4506 3454	113	708	1948–70	Trent
Finningley (combined with Lindholme)	125843	4658 3995	9	585	1946–70	Trent

TABLE 1C – STATION DETAILS FOR REGION 'C'

Station	Number	National grid reference	Alt.	1941–70 A.A.R.	Period of record	River Authority Area
			m	*mm*		
Ringway (combined with Barton)	564419	3818 3850	76	830	1934–70	Mersey & Weaver
Speke	567375	3415 3839	24	802	1954–70	Mersey & Weaver
Southport	569585	3371 4208	6	820	1928, 32, 38, 40–54	Lancashire
Coldwell Res No. 2	574785	3845 4375	293	1271	1952–66	Lancashire
Preston, Moor Park	576634	3537 4311	34	1000	1960–70	Lancashire
Squires Gate	577267	3316 4317	9	811	1948–70	Lancashire
Keswick, High Hill	593317	3260 5238	77	1519	1948–58	Cumberland
Spadeadam	603649	3599 5720	275	1213	1959–70	Cumberland
Carlisle (combined with Silloth)	606336	3384 5603	24	847	1949–70	Cumberland

TABLE 1D – STATION DETAILS FOR REGION 'D'

Station	Number	National grid reference	Alt.	1941–70 A.A.R.	Period of record	River Authority Area
			m	*mm*		
Boscombe Down	336376	4172 1393	128	716	1931–70	Avon & Dorset
Porton	339816	4210 1366	110	733	1954–70	Avon & Dorset
Hurn	346474	4117 0978	9	829	1954–70	Avon & Dorset
Exeter	355363	2995 0937	34	760	1947–70	Devon
Princetown Prison	363474	2586 0741	418	2131	1940–70	Devon
Mount Batten (Cattewater combined with Plymouth)	368487	2492 0529	27	999	1924–70	Cornwall
St Mawgan (combined with St Eval)	383478	1871 0642	104	972	1947–70	Cornwall
Chivenor	395162	2494 1347	6	851	1950–70	Devon
Torre (combined with Wooton Courtenay)	397808	3046 1400	43	923	1952–63	Somerset
Lyneham	412023	4012 1786	140	724	1946–70	Bristol Avon
Filton	418120	3598 1802	58	787	1937–70	Bristol Avon

TABLE 1E – STATION DETAILS FOR REGION 'E'

Station	Number	National grid reference	Alt.	1941–70 A.A.R.	Period of record	River Authority Area
			m	*mm*		
Shawbury	433710	3553 3220	70	684	1948–70	Severn
Worcester W. Wks	440198	3841 2565	18	648	1959–70	Severn
Pershore, College of Horticulture, (combined with Defford)	457134	3960 2450	40	642	1947–68	Severn
Ross-on-Wye	476390	3598 2233	67	717	1939–60	Wye
Rhoose	491860	3060 1670	6	908	1954–70	Glamorgan
Upper Lliw Res.	497879	2662 2058	183	1653	1959–68	SW Wales
Pembroke Dock	508580	1952 2033	10	1042	1948–57	SW Wales
Aberporth	517546	2247 2516	116	943	1946–70	SW Wales
Valley (combined with Holyhead)	532207	2310 3578	9	867	1924–70	Gwynedd
Wrexham	546162	3338 3507	82	786	1944–56	Dee
Hawarden (combined with Sealand)	549026	3342 3648	5	704	1922–56	Dee & Clwydd

TABLE 1F – STATION DETAILS FOR REGION 'F'

Station	Number	National grid reference	Alt.	1941–70 A.A.R.	Period of record	River Authority Area
			m	*mm*		
Acklington	005193	4225 6007	43	657	1947–70	Northumbrian
Forest-in-Teesdale	027035	3872 5295	381	1353	1946–66	Northumbrian
Darlington W. Wks	029582	4258 5139	49	581	1960–70	Northumbrian
Hartburn Grange	032602	4407 5185	31	559	1959–70	Northumbrian
Leeming (combined with Dishforth)	053904	4305 4890	34	628	1945–70	Yorks Ouse & Hull
Mount St John	055812	4474 4848	165	757	1936–56	Yorks Ouse & Hull
Bradford	075632	4149 4352	134	873	1960–70	Yorks Ouse & Hull
Pudsey S. Wks	076178	4324 4330	101	749	1960–70	Yorks Ouse & Hull
Halifax, Stannary	077997	4089 4257	168	859	1960–69	Yorks Ouse & Hull
Manby	136580	5391 3869	15	635	1952–70	Lincolnshire
Lincoln	141903	4962 3719	6	596	1960–70	Lincolnshire
Waddington	142001	4984 3650	67	592	1946–53; 55–70	Lincolnshire
Cranwell	146451	5003 3494	64	593	1924–70	Lincolnshire

TABLE 1G – STATION DETAILS FOR REGION 'G'

Station	Number	National grid reference	Alt.	1941–70 A.A.R.	Period of record	River Authority Area
			m	*mm*		
Wittering (combined with Cottesmore)	163918	5048 3032	79	573	1947–70	Welland & Nene
Cardington (combined with Cranfield)	174566	5081 2463	21	541	1947–70	Great Ouse
Mildenhall (combined with Honington)	187228	5683 2778	3	530	1935–70	Great Ouse
Marham	199124	5726 3094	24	600	1951–66; 1970	Great Ouse
West Raynham	206273	5847 3245	73	714	1948–68	E Suffolk & Norfolk
Felixstowe, Marsh Lane	221250	6314 2370	18	586	1924–35; 37–61	E Suffolk & Norfolk
Belstead Hall	222885	6126 2411	40	581	1942–60	E Suffolk & Norfolk
Shoeburyness	236466	5948 1857	3	516	1957–66	Essex
Lingfield S. Wks	293942	5384 1450	46	729	1939–67	Kent
West Malling	298019	5677 1553	95	669	1947–60; 64–68	Kent
Manston	301114	6335 1666	46	588	1935–39; 43–52; 65–70	Kent
Lympne	301621	6112 1355	107	721	1924–54	Kent
Canterbury S. Wks	302770	6166 1596	3	661	1961–70	Kent
Tangmere	320198	4911 1064	15	779	1947–60	Sussex
Thorney Island	321377	4756 1027	3	692	1942–45; 54–70	Sussex
Havant W. Wks	322335	4711 1063	9	719	1957–66	Hampshire
Calshot	331445	4488 1020	2	770	1920–40; 46–53	Hampshire

TABLE 2A – FREQUENCY OF SPECIFIED RAINFALL AMOUNTS WITHIN SPECIFIED DURATIONS (DAYS PER 100 YEARS), REGION A

Station	No. of years	⩽ 5 min		⩽ 7½ min		⩽ 10 min		⩽ 15 min			⩽ 30 min				⩽ 1 h				
		5 mm	10 mm	5 mm	10 mm	5 mm	10 mm	5 mm	10 mm	15 mm	5 mm	10 mm	15 mm	20 mm	5 mm	10 mm	15 mm	20 mm	25 mm
Digswell	(17)	88	12	-	-	200	18	265	59	0	-	88	18	0	-	147	71	29	0
Stansted	(14)	43	7	-	-	121	21	186	36	14	-	71	43	14	-	121	50	29	14
Camden Square	(42)	86	11	-	-	186	-	265	37	19	400	82	31	15	792	129	54	23	16
Northolt	(17)	60	12	-	-	133	24	220	35	12	-	76	35	18	-	118	53	35	18
Heathrow	(24)	73	0	-	-	207	37	273	50	8	-	96	29	4	-	183	67	25	17
Abingdon	(28)	60	4	-	-	147	14	227	25	7	-	61	18	7	-	129	39	21	11
Benson	(17)	64	0	-	-	155	18	228	24	18	-	88	18	18	-	158	53	18	18
South Farnborough	(47)	57	4	-	-	189	19	261	36	12	-	81	18	12	-	158	35	15	11
Camberley	(19)	-	-	50	11	-	-	200	26	5	400	58	16	0	917	132	26	11	0
Bovingdon	(16)	64	0	-	-	164	25	258	44	13	-	63	31	6	-	113	50	6	6
Lyne Farm	(19)	-	-	25	0	-	-	208	32	11	408	84	26	16	750	158	32	26	11
Shottermill	(29)	-	-	67	7	-	-	283	17	7	508	55	10	7	1075	149	21	10	10
Guildford	(28)	-	-	58	7	-	-	158	36	4	367	75	14	4	808	132	61	7	0
Woking	(21)	-	-	42	0	-	-	118	24	0	342	52	5	0	410	119	29	9	0
Earlswood S. Wks	(29)	-	-	50	3	-	-	117	21	3	341	66	21	0	833	121	35	0	0
Pixham Lane S. Wks	(29)	-	-	67	7	-	-	142	17	7	325	52	17	14	758	114	24	21	14
Leatherhead	(11)	-	-	75	0	-	-	200	27	0	375	82	36	0	850	173	45	18	9
Weyland S. Wks	(29)	-	-	83	14	-	-	175	31	7	408	62	21	14	767	121	41	21	17
Esher S. Wks	(16)	-	-	58	0	-	-	142	13	0	342	63	19	13	725	100	25	13	13
Epsom	(29)	-	-	75	10	-	-	175	28	7	375	100	31	7	833	141	62	24	7
Malden S. Wks	(26)	-	-	44	15	-	-	100	27	4	244	69	15	8	578	138	39	19	8
Hogsmill Valley S. Wks	(23)	-	-	67	9	-	-	100	30	4	378	83	9	9	767	135	35	13	13
Kingston	(26)	-	-	56	8	-	-	111	35	8	333	69	8	8	667	143	31	15	4
East Sheen	(26)	-	-	56	23	-	-	100	62	23	289	85	39	31	633	135	58	42	23
Kew	(33)	40	3	-	-	133	24	226	43	12	-	88	27	9	-	158	55	21	12
Old Malden	(26)	-	-	89	31	-	-	178	42	31	400	81	35	23	811	131	54	31	27
Sutton S. Wks	(26)	-	-	122	15	-	-	222	46	11	400	85	31	11	855	139	54	19	11
Raynes Park	(25)	-	-	89	8	-	-	167	24	4	400	68	28	16	733	128	48	24	16
Kingston Vale	(20)	-	-	122	5	-	-	189	40	0	356	80	20	10	744	135	45	25	10
Coulsdon	(26)	-	-	67	17	-	-	133	33	8	400	75	33	0	878	133	50	25	8
Woodcote Park	(26)	-	-	44	8	-	-	233	46	8	533	85	31	0	989	127	42	15	0
Purley	(12)	-	-	33	8	-	-	200	17	8	400	50	25	8	867	100	25	17	8
Waddon	(46)	52	7	-	-	163	20	230	28	24	-	61	27	21	-	124	42	30	9
Beddington Park	(26)	-	-	78	4	-	-	122	19	4	411	61	23	11	789	112	31	23	4
Morden Hall	(25)	-	-	56	8	-	-	122	31	8	378	73	27	11	667	111	46	27	8
Mitcham	(25)	-	-	44	4	-	-	189	44	8	333	80	24	12	600	136	60	20	8
Wimbledon	(26)	-	-	78	8	-	-	189	27	8	356	69	23	8	-	116	39	11	11
Greenwich	(17)	40	0	-	-	120	12	158	24	6	-	77	29	12	-	112	59	24	18
Median ('Average station')		59	4	63	8	158	20	188	31	7	379	74	24	10	782	130	44	20	10

TABLE 2A *(continued)*

Station	No. of years	⩽ 2 h				⩽ 4 h			⩽ 5 h			⩽ 8 h		⩽ 12 h		⩽ 16 h	⩽ 24 h
		10 mm	15 mm	20 mm	25 mm	15 mm	20 mm	25 mm	15 mm	20 mm	25 mm	20 mm	25 mm	20 mm	25 mm	25 mm	25 mm
Digswell	(17)	-	100	47	18	182	65	47	-	-	-	118	71	-	-	77	-
Stansted	(14)	-	86	43	14	171	86	7	-	-	-	157	100	-	-	150	-
Camden Square	(42)	267	89	31	18	257	100	57	-	-	-	186	100	-	-	186	-
Northolt	(17)	-	118	47	29	230	106	59	-	-	-	200	106	-	-	165	-
Heathrow	(24)	-	135	58	25	221	96	54	-	-	-	171	100	-	-	167	-
Abingdon	(28)	-	75	36	18	123	64	36	-	-	-	125	57	-	-	100	-
Benson	(17)	-	82	41	18	212	77	41	-	-	-	165	71	-	-	123	-
South Farnborough	(47)	-	97	35	19	211	73	38	-	-	-	191	79	-	-	158	-
Camberley	(19)	316	69	16	11	-	-	-	285	79	37	-	-	269	126	-	184
Bovingdon	(16)	-	69	19	6	156	50	25	-	-	-	156	69	-	-	131	-
Lyne Farm	(19)	332	116	55	21	-	-	-	248	121	68	-	-	237	121	-	184
Shottermill	(29)	422	93	31	17	-	-	-	400	124	55	-	-	428	190	-	362
Guildford	(28)	315	100	32	4	-	-	-	257	86	32	-	-	250	86	-	179
Woking	(21)	268	76	24	5	-	-	-	205	86	33	-	-	186	81	-	124
Earslwood S. Wks	(29)	269	79	17	0	-	-	-	286	83	21	-	-	252	93	-	234
Pixham Lane S. Wks	(29)	314	62	28	17	-	-	-	300	110	38	-	-	321	121	-	252
Leatherhead	(11)	473	127	27	9	-	-	-	455	118	36	-	-	300	118	-	173
Weyland S. Wks	(29)	242	72	28	21	-	-	-	193	69	31	-	-	159	62	-	135
Esher S. Wks	(16)	200	69	25	13	-	-	-	187	63	25	-	-	137	56	-	125
Epsom	(29)	300	103	35	17	-	-	-	296	117	28	-	-	200	100	-	152
Malden S. Wks	(26)	250	81	31	8	-	-	-	242	85	23	-	-	185	77	-	142
Hogsmill Valley S. Wks	(23)	269	83	22	13	-	-	-	209	52	26	-	-	170	61	-	131
Kingston	(26)	304	62	23	11	-	-	-	227	58	15	-	-	150	62	-	119
East Sheen	(26)	304	81	58	39	-	-	-	254	96	39	-	-	216	96	-	177
Kew	(33)	-	91	33	21	209	67	43	-	-	-	146	70	-	-	136	-
Old Malden	(26)	265	111	39	31	-	-	-	269	100	42	-	-	204	88	-	150
Sutton	(26)	296	89	39	11	-	-	-	273	112	19	-	-	250	96	-	165
Raynes Park	(25)	296	88	24	16	-	-	-	236	68	4	-	-	192	72	-	132
Kingston Vale	(20)	310	75	45	20	-	-	-	235	100	35	-	-	195	85	-	125
Coulsdon	(26)	275	93	25	17	-	-	-	267	83	33	-	-	217	100	-	233
Woodcote Park	(26)	338	85	27	15	-	-	-	288	108	27	-	-	261	111	-	231
Purley	(12)	275	83	17	17	-	-	-	208	75	25	-	-	208	83	-	158
Waddon	(46)	-	97	39	15	215	82	28	-	-	-	188	72	-	-	157	-
Beddington Park	(26)	273	73	27	8	-	-	-	273	85	15	-	-	238	81	-	165
Morden Hall	(25)	261	85	35	15	-	-	-	235	89	31	-	-	215	92	-	158
Mitcham	(25)	244	108	28	12	-	-	-	248	96	24	-	-	204	96	-	160
Wimbledon	(26)	238	73	35	15	-	-	-	215	69	31	-	-	165	73	-	107
Greenwich	(17)	-	82	35	18	165	71	29	-	-	-	118	59	-	-	94	-
Median ('Average station')		285	86	32	16	200	76	39	253	89	30	163	77	215	90	143	159

TABLE 2B – FREQUENCY OF SPECIFIED RAINFALL AMOUNTS WITHIN SPECIFIED DURATIONS (DAYS PER 100 YEARS), REGION B

Station	No. of years	⩽ 5 min		⩽ 10 min		⩽ 15 min			⩽ 30 min			⩽ 1 h				⩽ 2 h			⩽ 4 h			⩽ 8 h		⩽ 16 h
		5 mm	10 mm	5 mm	10 mm	5 mm	10 mm	15 mm	10 mm	15 mm	20 mm	10 mm	15 mm	20 mm	25 mm	15 mm	20 mm	25 mm	15 mm	20 mm	25 mm	20 mm	25 mm	25 mm
Keele	(14)	64	0	186	14	272	36	14	100	36	21	157	71	29	14	129	36	21	186	79	36	100	64	64
Elmdon	(21)	13	0	60	5	147	19	0	52	19	0	100	33	14	0	67	33	14	181	71	33	129	86	129
Lower Burbage	(20)	70	5	140	25	195	35	5	70	10	5	110	10	5	5	65	15	5	-	45	35	-	-	-
Watnall	(23)	60	4	140	13	174	43	13	78	17	9	113	61	22	9	83	35	13	226	87	26	209	117	183
Finningley	(25)	47	0	147	28	227	52	12	80	28	12	148	48	16	12	68	20	12	176	52	24	136	56	124
Median ('Average station')		57	1	142	17	198	38	10	76	21	9	123	47	17	9	72	30	13	183	68	31	133	75	127

TABLE 2C – FREQUENCY OF SPECIFIED RAINFALL AMOUNTS WITHIN SPECIFIED DURATIONS (DAYS PER 100 YEARS), REGION C

Station	No. of years	⩽ 5 min		⩽ 10 min		⩽ 15 min			⩽ 30 min			⩽ 1 h				⩽ 2 h			⩽ 4 h			⩽ 8 h		⩽ 16 h
		5 mm	10 mm	5 mm	10 mm	5 mm	10 mm	15 mm	10 mm	15 mm	20 mm	10 mm	15 mm	20 mm	25 mm	15 mm	20 mm	25 mm	15 mm	20 mm	25 mm	20 mm	25 mm	25 mm
Ringway	(37)	72	0	178	13	250	35	9	76	26	12	154	44	21	11	85	38	22	185	68	41	183	78	173
Speke	(17)	47	0	113	24	273	47	12	100	35	29	165	71	29	12	106	53	18	165	65	29	147	59	129
Southport	(18)	-	-	50	28	-	33	13	61	31	0	106	44	31	0	63	38	0	238	81	11	163	61	139
Coldwell Res. No. 2	(15)	127	7	220	40	300	53	27	100	27	7	140	33	7	7	67	27	7	-	80	40	-	-	-
Preston	(11)	64	9	155	0	227	27	9	64	9	0	127	36	9	0	118	27	9	227	64	27	-	-	-
Squires Gate	(13)	60	0	133	14	220	30	4	48	22	4	109	39	22	13	65	30	22	218	83	35	200	87	183
Keswick	(11)	67	0	100	18	167	27	18	73	27	9	173	36	18	18	173	64	27	718	255	145	798	418	764
Spadeadam	(12)	8	0	117	0	192	-	-	50	17	0	233	42	17	0	192	58	25	475	192	83	458	242	400
Carlisle	(22)	20	0	87	-	188	-	-	32	-	-	127	-	-	-	82	-	-	209	86	23	173	100	155
Median ('Average station')		59	0	123	17	222	33	12	65	25	5	142	40	19	7	91	40	18	223	80	34	203	97	184

TABLE 2D – FREQUENCY OF SPECIFIED RAINFALL AMOUNTS WITHIN SPECIFIED DURATIONS (DAYS PER 100 YEARS), REGION D

Station	No. of years	⩽ 5 min		⩽ 10 min		⩽ 15 min			⩽ 30 min			⩽ 1 h				⩽ 2 h			⩽ 4 h			⩽ 8 h		⩽ 16 h
		5 mm	10 mm	5 mm	10 mm	5 mm	10 mm	15 mm	10 mm	15 mm	20 mm	10 mm	15 mm	20 mm	25 mm	15 mm	20 mm	25 mm	15 mm	20 mm	25 mm	20 mm	25 mm	25 mm
Boscombe Down	(40)	38	0	110	17	181	27	3	47	9	3	113	28	8	5	56	21	13	188	56	17	141	47	160
Porton	(17)	33	6	93	18	173	24	6	82	12	12	112	47	18	0	77	24	12	254	82	29	194	59	189
Hurn	(17)	80	0	213	35	347	53	12	112	29	6	224	59	29	12	135	59	18	412	135	59	359	153	312
Exeter	(24)	80	0	200	21	320	42	13	92	46	13	167	71	38	13	125	67	17	392	154	42	304	75	179
Princetown	(21)	148	0	319	14	514	43	5	143	19	0	524	109	9	5	495	129	33	-	705	319	-	-	-
Mount Batten	(47)	63	0	163	16	263	27	6	67	21	6	178	39	24	9	121	36	16	463	155	42	479	153	347
St Mawgan	(24)	7	0	67	4	180	8	0	46	8	0	121	33	8	4	79	33	8	321	92	33	325	113	266
Chivenor	(21)	47	0	93	9	187	9	5	29	9	5	105	14	5	5	95	19	5	262	86	48	238	95	200
Torre	(12)	63	0	113	8	175	25	0	58	8	0	167	42	33	0	117	42	33	392	142	58	375	167	433
Lyneham	(25)	53	0	140	24	267	40	4	72	58	8	140	48	24	16	80	36	20	168	76	44	124	68	124
Filton	(24)	53	0	113	9	180	26	3	56	12	6	109	32	18	9	71	26	18	174	77	32	162	74	135
Median ('Average station')		56	0	129	15	219	29	5	67	15	5	142	42	19	7	99	35	16	304	108	42	264	93	214

TABLE 2E – FREQUENCY OF SPECIFIED RAINFALL AMOUNTS WITHIN SPECIFIED DURATIONS (DAYS PER 100 YEARS), REGION E

Station	No. of years	⩽ 5 min		⩽ 10 min		⩽ 15 min			⩽ 30 min			⩽ 1 h				⩽ 2 h			⩽ 4 h			⩽ 8 h		⩽ 16 h
		5 mm	10 mm	5 mm	10 mm	5 mm	10 mm	15 mm	10 mm	15 mm	20 mm	10 mm	15 mm	20 mm	25 mm	15 mm	20 mm	25 mm	15 mm	20 mm	25 mm	20 mm	25 mm	25 mm
Shawbury	(23)	73	0	153	9	227	21	4	78	13	9	108	39	13	9	74	35	17	183	65	22	148	61	122
Worcester	(11)	58	0	100	20	141	33	9	50	9	0	100	9	0	0	55	9	8	118	45	17	-	-	-
Pershore	(22)	23	0	115	19	238	33	9	76	24	14	157	38	14	9	100	38	9	152	71	29	119	52	110
Ross-on-Wye	(22)	68	0	187	18	305	41	0	95	14	5	146	27	14	14	73	27	18	-	82	36	-	-	-
Rhoose	(17)	33	0	133	6	200	29	0	82	29	6	158	47	24	18	124	53	24	424	177	47	353	165	288
Upper Lliw	(10)	10	0	110	10	310	10	0	40	10	0	210	40	10	0	200	40	10	920	310	100	1040	440	940
Pembroke Dock	(10)	0	0	-	10	150	10	0	90	20	10	220	40	20	10	150	30	10	630	180	80	500	240	440
Aberporth	(25)	33	0	73	8	133	12	0	52	8	0	120	32	0	0	80	16	0	264	84	12	272	88	264
Valley	(47)	39	2	125	9	200	17	3	40	6	3	109	23	9	2	59	18	4	256	62	28	235	85	211
Wrexham	(13)	-	8	-	31	-	39	8	62	-	0	100	39	15	15	69	15	15	169	39	15	139	62	139
Hawarden	(35)	38	0	94	14	181	20	15	46	20	15	109	40	20	9	55	25	11	135	50	17	110	37	106
Median ('Average station')		37	0	117	12	200	24	3	64	14	5	129	37	13	8	80	27	11	232	76	27	227	84	205

TABLE 2F – FREQUENCY OF SPECIFIED RAINFALL AMOUNTS WITHIN SPECIFIED DURATIONS (DAYS PER 100 YEARS), REGION F

Station	No. of years	⩽ 5 min		⩽ 10 min		⩽ 15 min			⩽ 30 min			⩽ 1 h				⩽ 2 h			⩽ 4 h			⩽ 8 h		⩽ 16 h
		5 mm	10 mm	5 mm	10 mm	5 mm	10 mm	15 mm	10 mm	15 mm	20 mm	10 mm	15 mm	20 mm	25 mm	15 mm	20 mm	25 mm	15 mm	20 mm	25 mm	20 mm	25 mm	25 mm
Acklington	(24)	20	0	53	0	100	8	0	33	0	0	46	21	4	0	46	13	4	183	46	17	167	50	142
Forest-in-Teesdale	(21)	29	0	57	5	129	9	0	33	5	0	91	24	5	-	81	14	9	-	114	43	-	-	-
Darlington	(11)	36	9	82	20	118	18	9	45	18	0	73	36	0	0	55	27	9	118	64	18	-	-	-
Hartburn Grange	(12)	45	0	100	18	142	27	0	58	18	0	108	33	17	0	58	33	17	125	67	17	133	50	75
Leeming	(26)	60	8	127	19	160	27	15	50	23	11	85	42	15	8	65	31	11	146	62	35	111	65	131
Mount St. John	(21)	104	-	180	8	256	28	4	48	8	4	84	16	4	4	52	16	8	-	44	24	-	-	-
Bradford	(11)	109	9	200	60	146	73	9	91	27	18	173	36	27	9	91	36	9	127	82	9	-	-	-
Pudsey	(11)	45	9	109	20	191	18	9	55	27	9	109	36	9	9	73	36	9	136	55	27	-	-	-
Halifax	(10)	22	0	78	0	111	22	0	44	11	0	133	22	22	11	67	22	22	189	89	22	-	-	-
Manby	(19)	20	0	87	5	160	21	0	58	5	0	105	32	5	0	53	37	16	158	42	16	116	42	100
Lincoln	(10)	60	10	120	60	170	30	20	60	30	30	110	30	30	20	100	40	20	160	74	40	-	-	-
Waddington	(23)	53	0	147	17	247	26	9	65	26	9	135	43	13	9	105	30	9	183	74	35	161	70	126
Cranwell	(47)	50	6	129	17	186	28	6	62	24	6	117	35	18	13	85	44	21	191	79	34	150	62	115
Median ('Average station')		45	4	108	15	156	24	5	53	18	4	104	32	12	7	69	31	11	156	67	25	140	57	119

TABLE 2G – FREQUENCY OF SPECIFIED RAINFALL AMOUNTS WITHIN SPECIFIED DURATIONS (DAYS PER 100 YEARS), REGION G

Station	No. of years	⩽ 5 min		⩽ 10 min		⩽ 15 min			⩽ 30 min			⩽ 1 h				⩽ 2 h			⩽ 4 h			⩽ 8 h		⩽ 16 h
		5 mm	10 mm	5 mm	10 mm	5 mm	10 mm	15 mm	10 mm	15 mm	20 mm	10 mm	15 mm	20 mm	25 mm	15 mm	20 mm	25 mm	15 mm	20 mm	25 mm	20 mm	25 mm	25 mm
Wittering	(24)	73	4	127	17	180	42	0	67	13	0	121	17	8	0	75	8	4	209	54	25	154	42	117
Cardington	(24)	27	0	47	4	120	13	4	29	13	0	88	25	8	0	50	17	0	138	46	17	100	37	71
Mildenhall	(36)	65	3	177	19	294	47	9	81	32	9	153	50	21	8	91	41	17	141	71	31	112	56	75
Marham	(17)	0	0	173	6	228	38	0	82	19	0	118	47	18	6	77	35	6	135	47	18	94	47	71
West Raynham	(21)	23	5	162	5	246	19	0	48	14	9	100	43	24	5	81	24	19	129	62	33	119	71	119
Felixstowe	(35)	72	3	150	13	233	22	8	49	12	4	129	32	8	5	72	28	11	168	64	30	128	51	84
Belstead Hall	(19)	74	-	179	26	268	69	21	89	37	16	179	63	37	11	95	47	16	-	74	26	-	-	-
Shoeburyness	(10)	30	0	110	20	160	20	10	50	20	20	100	20	20	20	70	40	20	130	70	40	250	150	150
Lingfield	(29)	33	-	-	-	200	28	21	85	28	10	145	52	10	7	114	41	7	-	-	-	-	-	-
West Malling	(18)	67	11	200	28	289	50	22	106	44	22	211	67	28	11	122	50	22	217	122	50	183	89	144
Manston	(21)	113	5	200	43	275	67	5	119	42	11	205	74	21	14	126	37	24	221	105	52	179	86	162
Lympne	(31)	85	0	185	32	261	52	6	106	28	11	168	61	28	7	117	50	23	250	94	48	183	93	184
Canterbury	(10)	60	0	210	10	250	20	0	80	20	0	180	50	10	0	90	30	0	160	90	30	140	80	110
Tangmere	(14)	80	0	220	21	380	43	7	86	29	0	179	43	7	7	100	36	7	264	64	21	186	57	221
Thorney Island	(21)	67	5	140	9	220	24	9	71	14	5	143	38	19	5	100	43	9	300	76	38	210	86	186
Havant	(10)	20	0	60	0	130	10	0	40	20	0	90	40	10	0	100	40	30	260	100	40	250	90	160
Calshot	(29)	24	0	100	10	165	24	0	66	17	0	145	42	8	0	75	42	7	292	92	31	232	83	162
Median ('Average station')		55	1	162	15	232	32	5	75	22	5	144	45	15	7	90	38	12	195	75	32	165	74	136

TABLE 3 – SUMMARY OF MEDIAN VALUES FOR THE 'AVERAGE STATIONS' (FROM TABLES 2A–2G)

Area	No. of years	⩽ 5 min		⩽ 10 min		⩽ 15 min			⩽ 30 min			⩽ 1 h				⩽ 2 h			⩽ 4 h			⩽ 8 h		⩽ 16 h
		5 mm	10 mm	5 mm	10 mm	5 mm	10 mm	15 mm	10 mm	15 mm	20 mm	10 mm	15 mm	20 mm	25 mm	15 mm	20 mm	25 mm	15 mm	20 mm	25 mm	20 mm	25 mm	25 mm
A	941	59	4	158	20	188	31	7	74	24	10	130	44	20	10	86	32	16	200	76	39	163	77	143
B	103	57	1	142	17	198	38	10	76	21	9	123	47	17	9	72	30	13	183	68	31	133	75	127
C	156	59	0	123	17	222	33	12	65	25	5	142	40	19	7	91	40	18	223	80	34	203	97	184
D	272	56	0	129	15	219	29	5	67	15	5	142	42	19	7	99	35	16	304	108	42	264	93	214
E	235	37	0	117	12	200	24	3	64	14	5	129	37	13	8	80	27	11	232	76	27	227	84	205
F	246	45	4	108	15	156	24	5	53	18	4	104	32	12	7	69	31	11	156	67	25	140	57	119
G	369	55	1	162	15	232	32	5	75	22	5	144	45	15	7	90	38	12	195	75	32	165	74	136
Mean	332	53	1.4	134	16	202	30	6.7	68	20	6.1	131	41	16	7.9	84	33	14	213	79	33	185	80	161
Bilham/ Holland	120	55	3	149	25	223	35	9	73	22	8	146	44	18	9	88	36	18	176	72	36	144	72	144